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Publication date:
2015

Document Version
Peer reviewed version

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PO.281

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Abstract

The load alleviation potential of the Controllable Rubber Trailing Edge Flap (CRTEF) is verified on a full Design Load Base (DLB) setup using the aeroelastic code HAWC2, and by investigating a flap configuration for the NREL 5MW Reference Wind Turbine (RWT) model. The performance of the CRTEF configuration is evaluated in terms of fatigue damage equivalent loads and ultimate loads by comparing four setups: 1) base line with collective pitch, 2) individual pitch control, 3) CRTEF and 4) CRTEF combined with individual pitch control. The CRTEF allows for a significant reduction of the lifetime fatigue on various load channels; the reduction for some of the extreme loads is also noticeable.

Objectives

The load alleviation potential of using active flaps on wind turbine rotors has been investigated in the past decade using various models, controllers, configurations and load cases [1]. In this work, the aeroelastic load simulations present a first approach for documenting such an evaluation on an overall realistic setup.

Main characteristics of the simulations:

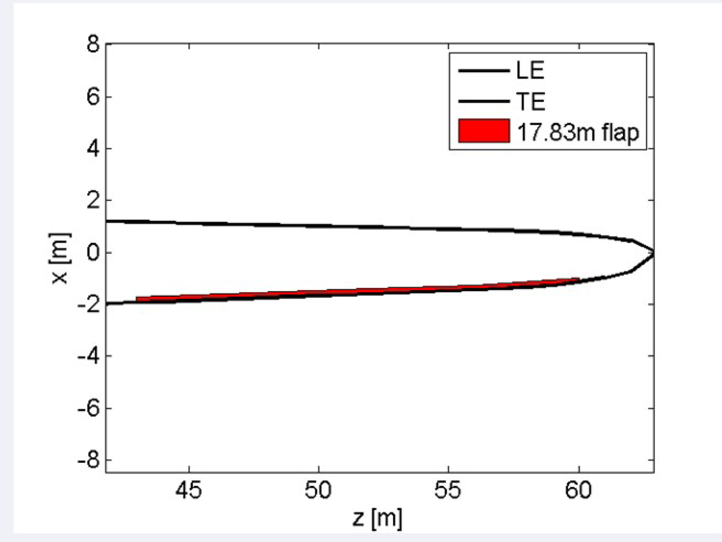
- Certification-type design load base setup close to industrial standards
- Representative wind turbine / flap system configuration
- Realistic controllers for full range of operation

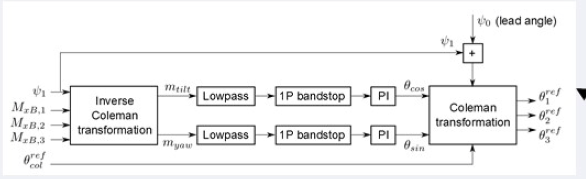
Methods

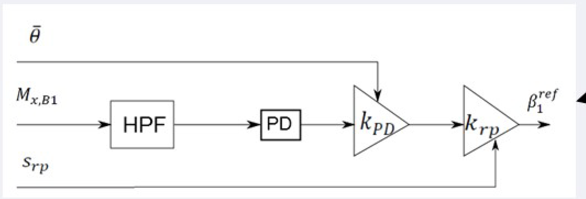
- DTU Design Load Basis (DLB) [2]
  - Full DLB that follows the current design standard and is representative of a general industry DLB
  - Following design requirements of IEC 61400-1
  - Extreme and Fatigue load evaluation on representative load channels
- Wind turbine model
  - NREL 5MW Reference Wind Turbine
  - An active flap covering 30% of blade length with CRTEF characteristics [3]
  - DTU's HAWC2 aeroelastic code including the ATEFlap dynamic stall model for flaps
- Controllers
  - Baseline power regulation
  - Individual Pitch Control (IPC) (tilt-yaw controller)
  - Individual Flap Control (IFC) (independent blade controller)
  - Combined IPC & IFC

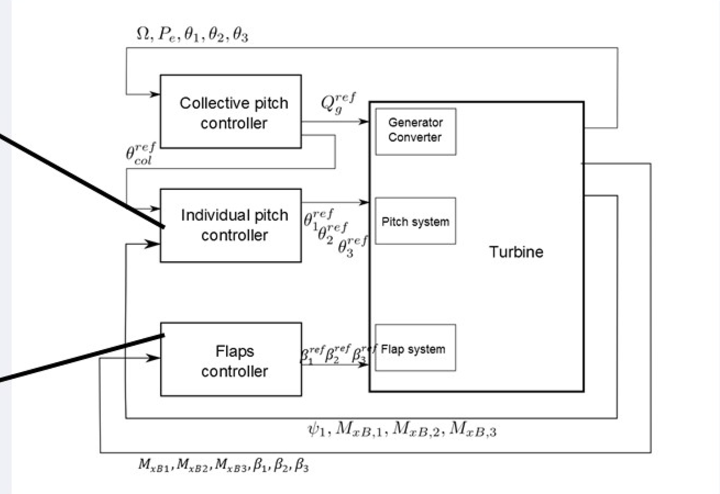
Active flap configuration

Chordwise extension	10%
Deflection angle limits	±10°
Spanwise length	17.8m (29% blade length)
Spanwise location	43.05m-60.88m
Airfoil	NACA64618
Max ΔC_l	0.4
Deflection rate limit	100°/s
Actuator time constant	100ms



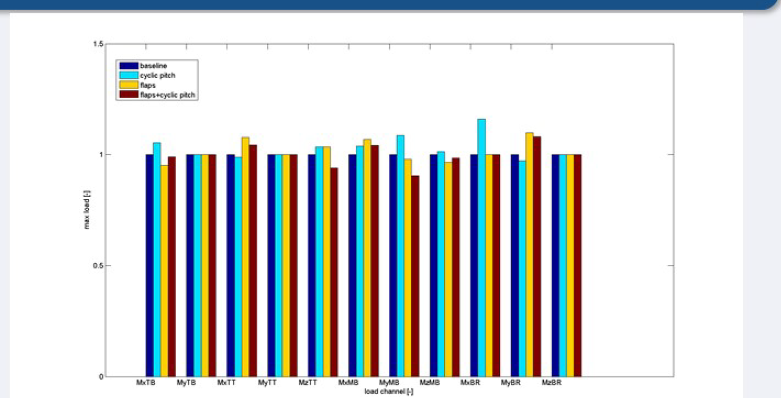


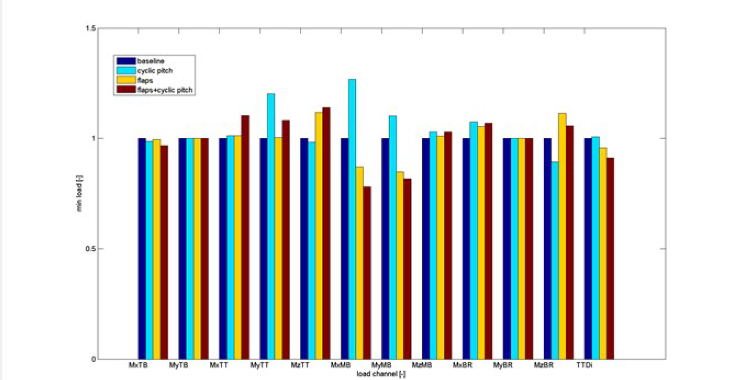


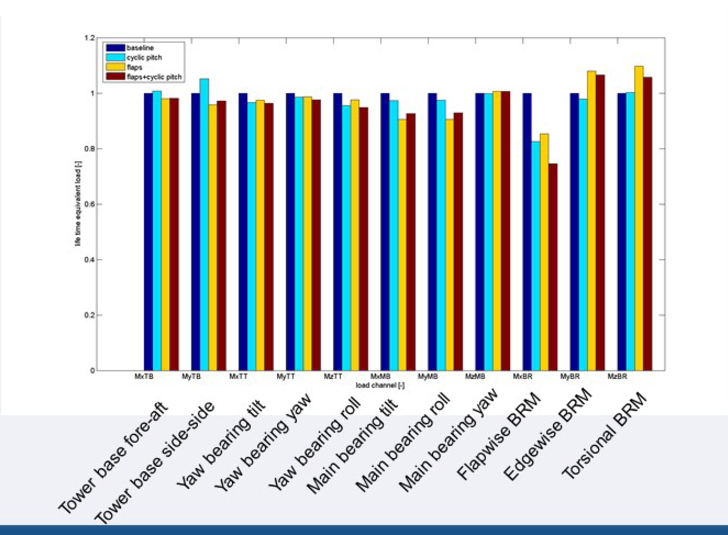


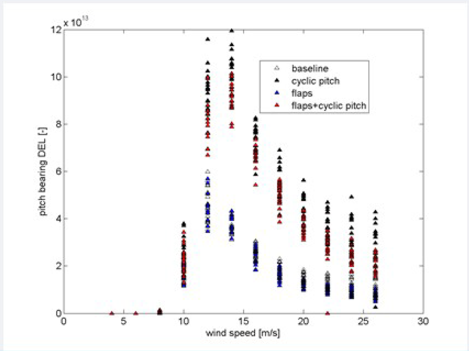
Results

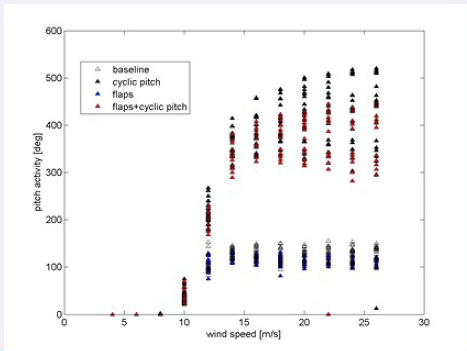
- Lifetime fatigue loads
  - IPC and IFC have a significant fatigue load alleviation impact on blade, main bearing and tower loads, ranging from 2% to 17%.
  - Combined IPC and IFC shows the best fatigue load alleviation performance, with alleviation up to 25 % on the blade root flapwise bending moment, 7 % on the main bearings, and from 2% to 5% on the tower loads
- Extreme loads
  - IPC can decrease extreme loads up to 11% (M_zBR), while IFC up to 16%(M_yMB) and combined control up to 22%(M_xMB). The impact on extreme loads is very sensitive to specific controller parameters on fault cases
- Actuator use
  - Pitch activity for IPC configuration is ten times higher than the baseline one, while pitch bearing equivalent damage increases by a factor of two
  - IFC slightly reduces pitch bearing equivalent damage compared to IPC (3.4%)
  - Combined IPC & IFC reduces total pitch bearing travelled distance by 20 % compared to IPC

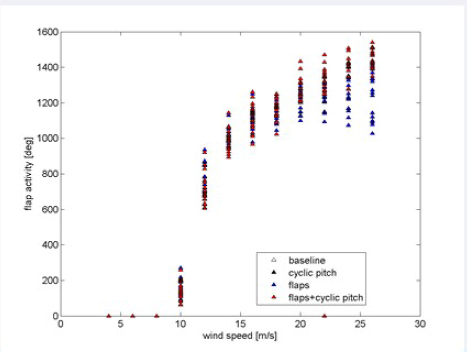












Conclusions

- Realistic evaluation of IPC & IFC on a full design load basis
- Significant reduction of lifetime fatigue on various load channels with IPC, IFC and combined control. Potential for reduction of certain extreme loads
- Significant impact of IPC on pitch bearing wear. Slight reduction of pitch use with combined controls.

References

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